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LLNL touts gamma-ray source for nuclear detection

Lab also sees applications in monitoring isotopic content of reactor fuel and assaying nuclear waste.

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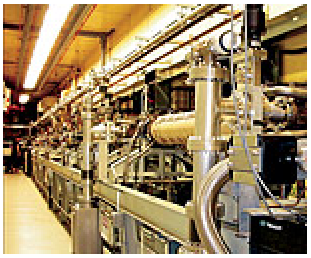

The 40-year-old Thomson-Radiated Extreme X-ray Source accelerator at Lawrence Livermore National Laboratory was modified to produce megavolt beams of mono-energetic gamma rays,

Scientists at **Lawrence Livermore National Laboratory** are developing a new gamma-ray scanning system that they say could greatly improve the ability of customs inspectors to detect nuclear weapons materials being smuggled into the US, without impeding the flow of commerce.

Using a 40-year-old mothballed accelerator with the improbable acronym T-REX, for Thomson-Radiated Extreme X-ray Source, the lab generated a laser-like beam of nearly one megavolt of mono-energetic gamma rays. Through a technique called nuclear resonance fluorescence, the researchers were able to excite atoms in a piece of lithium that was shielded behind sheets of lead and aluminum, thereby revealing the lithium's presence.

The results show that the technique could locate even the lightest elements screened behind dense shielding, says principal investigator Christopher Barty. "We think that it's going to open up a whole raft of detecting, assaying, and imaging applications." Since the gamma rays produced can be tuned to the resonance frequency of any atomic isotope, the technology will discriminate between uranium-235 and uranium-238, he notes. That could give operators of nuclear power stations the ability to more precisely determine in situ when the reactor fuel becomes depleted and refueling is needed, he explains. Currently, operators can only guess when it's time to refuel, and their estimates may be off by as much as 30% either way.

"You can do the analysis in situ, in the pipes, or in the reactor, to find out what the fuel content is," Barty says. "And that would lead you to the scenario where maybe you could come up with a reprocessing story that has no proliferation issues—a completely closed cycle." The technology could also be used to verify the contents of an estimated 25 million barrels of nuclear waste left over from US nuclear weapons production and to double-check whether the materials were properly labeled as high- or low-level waste. "We think we can make a 3D tomograph of the entire nuclear waste contents," Barty says.

Internal funding used

Funding for the project is supplied from the laboratory-directed R&D program, in which managers of Department of Energy national laboratories are allowed to decide how to spend a portion of their annual budgets (see Physics Today, October 2009, page 23). The initial three-year, $9 million LDRD was completed in September 2008. The second project, funded at $4 million annually for three years, got under way the following month. It includes the design of a compact gamma-ray source that will provide three to five orders of magnitude more flux than the

T-REX. The lab plans to spend another $3 million to prepare the facilities to house the new machine.

Based on a rule of thumb in the laser industry—the sales price is roughly three times what the parts cost—the unit cost of a gamma probe system will be roughly $2 million, Barty estimates. A full engineering-based cost estimate is under way. In an application of inverse Compton scattering, lasers are fired at relativistic electrons produced in an accelerator. The interaction with the energetic electrons kicks up the photons into gamma rays.

“We take a few MeV electrons, and we can make megavolt-range, gamma-ray light,” Barty says. “The brightness that you get in the megavolt machine is extraordinary: It can be 15 orders of magnitude beyond the brightness of the best synchrotrons at a megavolt.” The angular spread of the gamma beam, around a milliradian, is about the same as the light from a common laser pointer. Barty says the lab has designs to adapt the beam for scanning.

Excessive false alarms

The Domestic Nuclear Detection Office (DNDO), part of the Department of Homeland Security, has been aiming since 2006 to install improved portal monitors at the nation’s ports, through which about 48 million containers enter each year. The existing polyvinyl toluene monitors are unable to distinguish threat materials such as plutonium and highly enriched uranium (HEU) from harmless, slightly radioactive substances like kitty litter and ceramics. The rate of false alarms is high, and each false positive requires a 15-minute manual follow-up inspection by a customs agent equipped with a hand-held monitor.

The procurement of advanced spectroscopic portal (ASP) detectors capable of greater selectivity in the hunt for weapons-usable materials has been delayed several years by the DNDO due to that system’s mixed test results. The LLNL gamma-ray probe is one of a number of candidates the DNDO is evaluating for a yet more advanced system meant to solve the problem of finding HEU that might be shielded against detection in cargoes. That will require systems that actively probe containers, as LLNL’s does with gammas. Barty says the lab has recently initiated two three-year R&D projects for DNDO: development of higher-flux and more compact gamma sources, and the identification and characterization of detection geometries for nuclear materials of interest, with nuclear resonance fluorescence as the base technology. DNDO is providing about $2 million a year to those projects. The nuclear nonproliferation program at the Department of Energy, he adds, also is interested in the technology for its potential use at foreign ports and in the verification of arms control agreements.